REMARKS

Reconsideration and withdrawal of the rejection with respect to all of the claims now in the application (i.e., Claims 8-11) is respectfully requested in view of the foregoing amendments and the following remarks.

By this Amendment, the claims have been amended to provide proper antecedent basis for certain elements and to be consistent in the wording referring to the "refraction index dispersion" and the "transformation unit". In addition, Claim 9 has been amended to define that the apparatus "includes means" to compute the thickness of the film. Claims 8 and 10 have also been amended to set forth that the oscillations obtained by fast Fourier transformation (FFT) "is based on" (or reflects) the refraction index dispersion in the Fourier analysis, rather than "adapts". Support for this language can be found in the specification on page 17, line 21, page 18, lines 3-4, 12-13, 15, page 22, line 6, page 23, line 18 and page 24, line 8 and Fig. 3, step S40.

It is respectfully submitted that Claims 8-11, as now amended, are not obvious in light of Horie (U.S. Patent No. 5,440,141). The present invention, as now claimed, provides a more accurate method to determine a film's thickness by performing an improved fast Fourier transformation ("FFT") based on or reflecting the refraction index dispersion. In particular, as set forth in Claims 8 and 10, the thickness of a thin film is computed based on the number of oscillations which is obtained as a result of a

fast Fourier transformation. In the improved fast Fourier transformation, the digital signal data is transformed by the transformation unit based on the refraction index dispersion.

Simply stated, a fast Fourier transformation is an efficient algorithm which transforms one function into another function. The position of the Fourier peaks are determined by the refraction index, but as shown in Figure 6A of the present invention, the refraction index of the film varies over wavelength. Since there are different refraction indexes based on the wavelength, a problem which occurs in the prior art is that the interval of peaks in the Fourier transformed spectrum are changed so that the heights are slightly decreased and widths increased because the refraction index of the film has not been taken into consideration. (See specification pg. 5, lines 11-17) As a result, the periods of the oscillations are not constant and the determination of the thickness of the film is less accurate. Therefore, since there is a dispersion of the refraction of a thin film (nf) in the material of the thin film, it is necessary to measure the films thickness based on the refraction index dispersion. (See specification, pg. 17, line 20-pg. 18, line 1).

The present invention specifically overcomes this problem by performing an improved fast Fourier transformation based on the refraction index dispersion. As a result of the method as presently claimed, the Fourier transformed spectrum obtained by FFT is directly related to the film's thickness and thus allows for a more accurate calculation of film thickness.

In contrast, Horie simply represents the state of the prior art which provides for a method that is less accurate in measuring a film's thickness and has the same problems as mentioned above. Horie relates to a method of calculating thicknesses of films in a multilayered sample wherein an oxide film, a nitride film, or both are disposed on a SOI substrate. In the Horie method, the thickness of the top layer film is determined by using the equation conventionally used in the prior art, irrespective of FFT. Although, the refraction index dispersion is considered in this step, this step is performed <u>before</u> FFT. In the second step, FFT is performed but based on the <u>averaged</u> value of the refraction index and not the <u>dispersion</u> of the refraction index.

Therefore, Horie considers the refraction index dispersion <u>before</u> performing FFT by the equation conventionally used in the prior art and after FFT is performed, Horie takes into consideration the <u>averaged value of the refraction index</u> to reduce error not the refraction index dispersion. As a result, the same problems as in the prior art mentioned above occur in the Horie method namely, that since there are different refraction indexes based on wavelengths the interval of the peaks in the FFT are slightly decreased and widths increased because the refraction index of the thin film is not taken into consideration. Thus, since the periods of the oscillations are not constant, the calculation of the film's thickness is not accurate. (See specification, pg. 5, lines 11-17) The present invention specifically addresses and overcomes these problems and provides for a more accurate method to measure a film's thickness by performing an improved FFT based on the refraction index dispersion, (see Claim 8)

which is not disclosed or suggested by Horie.

More specifically, Horie is a method for measuring film thicknesses of a multilayered sample in which one or two transparent films are disposed on an SOI substrate($Si/SiO_2/Si$) which consists of a crystalline silicon, a transparent insulation film and a monocrystalline or polycrystalline silicon film (Col. 1, lines 9-15). Figures 15 and 16 show a cross-section view of the SOI substrate.

In the sample illustrated in Figure 15, a silicon oxide film 3 is disposed on the SOI substrate 10 or as illustrated in Figure 16 both a silicon oxide film 3 and a silicon nitride film 4 are formed on the SOI substrate 10. As a result, the film thicknesses measured in the silicon oxide film 3 of Figure 15 and in the silicon oxide film 3 and the silicon nitride film 4 of Figure 16 are d3, d2, and d1. The method to determine each film's thickness in the sample with the silicon oxide film 3, is described more particularly, as follows. The same method can be similarly applied to the sample in Figure 16 with both the silicon oxide film 3 and the silicon nitride film 4.

Step1: The reflection ratio spectrum (i.e., a peak and valley) of the reflection ratios $Rm\lambda$ of the first wavelength range (200 nm to 350 nm) is measured.

Step2: d3', which is an approximate value of the thickness d3 of the silicon oxide film 3, is calculated by a peak detection and curve fitting method. More particularly, d3' is calculated by Equation 2 from the wavelength and the corresponding refractive index, of the peak or valley, of the reflection ratio spectrum measured in Step 1 (see, Col. 9, lines 36-37). In Eq. 2, n1 and n2 represent the

refractive indices of the silicon oxide film at the wavelength λ1 and λ2, respectively, (of a peak or a valley). Therefore, in this step the refractive index dispersion is used to calculate the film's thickness. Equation 2 is frequently used in determining thicknesses of optical thin films. <u>However, FFT is not performed in this step</u>.

Step 3: An approximate value d2' of the thickness d2 of the silicon film is calculated by performing FFT (See Figs. 2 and 6 and Col. 10, lines 42-51). During this step, the spectral reflection ratio data with respect to the second wavelength range (e.g., 400 nm to 1,000 nm) is measured and utilized. The spectrum of the measured reflection ratio in this second wavelength range reflects the interference effect of the silicon film.

Following this, an interference waveform in the wavenumber space (wavenumber is defined as the inverse of wavelength, and is proportional to photon energy) previously calculated is Fourier transformed (FFT) to obtain a Fourier transformed spectrum. From the Fourier transform spectrum, a power spectrum as shown in Figure 7 is derived. (Col. 10, lines 63-66).

In the wavenumber space, the reflection ratio spectrum shows a periodic oscillation with a <u>nearly uniform</u> interval whereas the reflection ratio spectrum in the present invention has a <u>perfectly uniform</u> interval or an equal interval and uses the space where the wavenumber is multiplied by the refractive index. The effective optical path length of the corresponding thin film is then obtained by calculating the number of these oscillations per unit wavenumber. To calculate the number of

oscillations, FFT is performed.

After performing FFT to acquire the power spectrum (such as Fig.7), the peak (P2) corresponding to d2 is determined and d2' which is the approximate thickness of silicon film 2, is calculated by dividing the effective optical path length related to peak P2 (=n2 X d2) by the average refraction index <n2> of the silicon film 2 for the second wavelength region. Thus, in this step, FFT is performed and the film's thickness is calculated based on the average refraction index <n2>, not the refraction index dispersion as in the present invention.

Step 4: Calculates d1', which is the approximate value of the thickness of the silicon oxide film 1(d1), by using a low-pass filtering technique (Col. 11, lines 24-26). In this step, low pass filtering is used to eliminate the interference effect by the silicon film. This is achieved by utilizing inverse Fourier transformation after nulling the high frequency component of the Fourier transformed reflection ratio spectrum. Thus, the spectral reflection ratio data is obtained in a manner similar to Step 3, but does not include interference components caused by the silicon oxide film 2. Therefore, the interference waveform W13 in Figure10 is equivalent to combination of the interference waveform derived on the silicon oxide film 3 (with a thickness d3) and silicon oxide film 1 (with a thickness d1)(Col. 11, lines 58-64). In the following step, a theoretical waveform WT3 is calculated from irradiation of light of the second wavelength region of silicon oxide film 3, with a thickness d3 (W1 in Fig.10), by subtracting W1 from W13. Using WT3, d1' is calculated in the same method of a

peak detection and curve fitting as that used in calculating d3'.

Step 5, 6: By changing the thickness d1 and d2 of silicon oxide films 1 and 2, respectively, by fixed amounts, the optimum value of d1 and d2 are determined on the condition that E has the minimum deviation.

Step 7, 8, 9: A quadratic surface approximation is performed utilizing the least square method (Col. 13, lines 59-62). As a result, the thicknesses d1 and d2 are determined having the smallest quadratic surface. If E is found to be within the acceptable error bounds, the equations are solved and the final results are obtained, ending the process and thus, measuring the film's thickness.

In summary, Horie relates to a method of calculating thicknesses of films 3 or 4 of the multilayered sample wherein the oxide film or the nitride film/oxide films are disposed on the SOI substrate. According to the Horie method 1) first, the thickness of top-layer oxide film or nitride film/oxide film is obtained by using the equation conventionally used; 2) the thickness of the silicon film is found by using FFT; 3) the thickness of the underlying oxide film is obtained through low-pass filtering and inverse FFT; and 4) all film thicknesses are determined by an optimization process and minimization process. In Horie, the dispersion of the refraction index is used in step 2 when using the conventional equation, however, this step is performed <u>before FFT</u> which is performed in Step 3. In Step 3, FFT is performed based on the <u>average refraction index</u> and not <u>dispersion of the refraction index</u>.

In contrast to Horie, the presently claimed invention provides a method of

improving the accuracy of determining film thicknesses by considering the refraction index dispersion in the FFT procedure. More specifically, when performing FFT, the reflection ratio spectrum is defined as the y-axis and the photon energy, which is proportional to the inverse of wavelength multiplied by refraction index, is defined as the x-axis. After FFT, the peak position of the Fourier transformed spectrum is related to the film thickness. Since the refraction index dispersion has already been considered in FFT, after FFT the x-axis of the graph becomes thickness, and the peak of the Fourier transformed spectrum is much sharper and narrower, as depicted in Figure7B. Therefore, by the presently claimed method it is possible to determine the thickness of a film accurately irrespective of the dispersion of the refraction index since the FFT was performed based on the refraction index dispersion.

In contrast, in Horie, after performing FFT, the x-axis becomes the effective optical path length(n2xd2) as depicted in Figure 7. To obtain the film thickness (d), the effective optical path length is divided by the refractive index (n2), and at this step, the average refractive index <n2> is used to minimize error. However, as depicted in Figure 6A of the present invention, the refractive index of the film varies over wavelength, thus, when the method in Horie is used, there is a problem of not obtaining the accurate value of d2. This is the same as the problem in the prior art pointed out in the present invention and this deficiency was addressed in the present invention.

Therefore, even though Equation 2 as used in Step 2 of Horie discloses calculating the dispersion of refraction index to obtain film thickness(d3), this is the same equation conventionally used in the prior art. This Equation is applied irrespective of using FFT, which is performed at a later step. Further, when FFT is performed in Step 3, the refraction index dispersion is not considered. In Step 3, film thickness(d2) is obtained based on the averaged value of the dispersive index of refraction after FFT. Hence the method in Horie is totally different from the present invention and does not suggest the claimed method of the present invention which performs an improved FFT based on the refraction index dispersion which leads to a more accurate calculation of the film's thickness.

Finally, Applicant would appreciate the Examiner's confirmation in the next Office Action whether the drawings previously submitted are acceptable.

Applicant hereby requests a one-month extension of time in which to respond to the outstanding Office Action. Credit Card payment form no. PTO-2038 in the amount of $60.00 is enclosed . Any fee deficiency or overpayment may be charged or credited to Deposit Account No.50-3990.

In view of the foregoing, it is respectfully submitted that the present invention as now set forth in Claims 8-11 is patentable over the cited are and, therefore, allowance of the aforesaid claims at an early date is earnestly solicited.

Respectfully submitted,

KIM ET AL.

Thomas M. Galgano, (27,638)
GALGANO & ASSOCIATES, PLLC
Attorneys for Applicant
20 West Park Avenue, Suite 204
Long Beach, New York 11561
Telephone: (516) 431-1177

TMG/jgb/jgg
Enclosure: USPTO Form 2038 in the amount of $60.00
Postcard
F:\G&b\1834\2\amendment2.wpd